The effects of supplementary feeding and weather factors on the breeding success of Osprey, *Pandion haliaetus*, in Finland

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Tiivistelmä - Referat - Abstract

Osprey *Pandion haliaetus* has been under a strict surveillance of the nature conservationists and a conservation icon since the early 70’s. At that time the accumulation of persistent environmental toxins and pollutants lowered the populations of many birds of prey to low levels, threatening the survival of entire species. Nowadays osprey is one of the successful models of endangered species protection. Because of its status osprey is very thoroughly studied raptor. Due to environmental toxins many birds of prey suffered from eggshell thinning and lost clutches till the end of 1970’s. Eggshell thinning has later stopped and is now reverting, but after the start of intense studying of the birds other threats have been observed to reduce reproductive success. Many earlier studies have suggested that extreme weather conditions may have an effect on the nesting success of diurnal birds of prey. In osprey´s case many researchers have examined the effects of different weather patterns to foraging success and food delivery, but a specific review over their effects on the nesting success hasn’t been conducted so far.

In this study I focus on the effects of different weather factors and their contemporary nesting success. I study a nature conservation based supplementary feeding pond‘s effect to the local osprey population’s reproductive success, combined with the weather variables and the density of nesting pairs. Osprey is recorded to fly approximately 3–15 km on its foraging trips. At their longest these fishing trips can be over 40 km long one-way. The Osprey Center, working in Pohtiolampi at Kangasala (61° 26.876' N, 24° 7.705' E), in Southern Finland, feeds the local ospreys with living rainbow trout from an old fish farm pool. In theory, the birds nesting or living near the supplementary feeding pond benefit from this in a form of easy sustenance. The fish move near the water surface and are thus available all the time. Especially during bad weather conditions the pond is frequently visited by nesting ospreys. In this study I examine 1) does supplementary feeding have an effect on the nesting success of the local osprey population, 2) what is the role of weather factors affecting the breeding success and 3) does supplementary feeding have an effect on nesting density?

I used 16 years of weather and breeding data (1997–2012) and evaluated the individual and combined weather variables and their possible effects on nesting success and brood production, comparing study and control area. I set my study area in a shape of a circle with 30 km radius. Pohtiolampi feeding pond was placed in the center of the study area, surrounded by a vast labyrinthine lake area. For the control area’s and study area's ecosystems to be as much alike as possible, I established the control area, also in a form of a circle and continuing the next 30 km, to start where the study area ended (see: Map 1.). I calculated the covariance and Akaike weights of different weather variables and annual nesting success with R (2.15.0) statistical calculation program. Collinearity was assessed with variance inflation factors (VIF). Generalized linear mixed models (GLM), to asses simultaneously the role of weather variables and the nesting success of both study and control area, were used. Finally the scenarios were arranged in significance order by their AIC_c values (Akaike information criterion adjusted for finite sample size). After the comparing analysis, I repeated the calculations also without the division to study and control area, gaining information about the effects of weather variables in general. I also calculated the proportional effects of different land use types to the nesting density of the local osprey population by using ArcGIS mapping tool and compared the results between study and control area.

My results indicate that supplementary feeding does not influence the nesting success. Same annual average of young fledged the nests each year, regardless of the area. Weather variables, however, showed some effect on the nesting success when viewing the entire population. The assembled weather data shows examples of weaker nesting success in summers with prolonged storms, rainy weather or low average temperature. However, levels of significance, derived from the data, are still too low to be used as generalizations. Only three day long storms had a better AIC weight than the null model. I presume that the good fishing waters, wind shelter and shoreline forests are possible explanations to this trend. Most harmful weather to the osprey nestlings was a prolonged storm (≥ 7 m/s wind) and rainy summers. The nesting density of osprey was recorded to be significantly higher in the study area than in the control area, when viewing the total land acreage. Moreover, I recorded that the density in the study area grew up to almost four times the number of control area, when studying the acreage of potential nesting areas. When viewing the area of foraging waters the difference was reduced to 1.5 fold. I conclude that the local osprey population benefits from the supplementary feeding area by nesting more densely near the abundant food source and thus producing more young per km^2.

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nesting success, osprey, Pandion haliaetus, weather, weather dependence, nestling, hatchling, mortality

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Tiivistelmä - Referat - Abstract

Kalasääski *(Pandion haliaetus)* on ollut luonnon- ja petolintusuojelun ikoni 70-luvulta lähtien. Silloin ympäristömyrkkyjen seurauksena vähentyneet kannat laskivat huolestuttavan alhaisille tasoille. Nyttemmin kalasääski on yksiä menestyksekkäimpiä esimerkkejä toimivasta lajinsuojelutyöstä. Statuksensa takia kalasääski on hyvin tutkittu laji. Ympäristömyrkkyjen vaikutuksesta monien petolintujen munankuorien huomattiin 70-luvulla ohentuneen ja haurastuneen. Kuoret ovat sittemmin palautuneet luonnolliseen paksuuteensa, mutta muiden uhkien on huomattu vähentävän pesintämenestystä. Petolintututkimuksessa on monesti epäilty säämuuttujien vaikuttavan lajien pesintään. Kalasääsken kohdalla on tutkittu useaan otteeseen sääolojen vaikutusta yksilön saalistuksen onnistumiseen ja ravinnonsaantiin, mutta tarkkaa kartoitusta niiden vaikutuksesta linnun pesintämenestykseen ei ole toistaiseksi tehty.

Tässä tutkimuksessa keskityn eri säätekijöiden vaikutukseen kalasääsken pesintään Etelä-Suomessa. Lisäksi tutkin lisäruokinnan vaikutusta kalasääsken menestymiseen. Kalasääski lentää ravinnonhakumatkoillaan keskimäärin 3–15 km päähän. Pisimmillään matka saattaa olla jopa yli 40 km. Kangasalan Pohtiolammella toimiva Sääksikeskus ruokkii sääksiä elävillä kaloilla altaasta. Tämän kala-altaan lähettyvillä pesivät ja liikkuvat sääkset käyvät usein lammella, jossa kirjolohen saaminen on käytännössä aina varmaa. Etenkin sään ollessa huono luonnon vesillä, sääksiä vierailee lammella paljon. Tutkimuskysymyksinä olivat: 1) vaikuttaako lisäruokinta kalasääsken alueelliseen pesintämenestykseen, 2) mitkä ovat sääolojen vaikutukset vuotuiseen poikastuottoon ja 3) kasvattaako lisäruokinta pesimätiheyttä ravintoaltaan läheisyydessä?

Asetin koealueen säteeltään 30 kilometrisen ympyrän muotoon, Pohtiolammen ravintoaltaan ympärille. Kontrollialue jatkui vastaavasti koealueen reunalta, myös ympyrän muodossa, seuraavat 30 km. Käytin aineistona vuosien 1997–2012 säädataa ja pesätietokantaa. Tutkin tilastolaskuohjelman (R 2.15.0) avulla eri sääolojen yksittäisiä ja mahdollisia yhteisvaikutuksia verraten keskenään koe- ja kontrollialueen vuosittaisia pesäpoikastietoja. Aineiston kollinearisuus tutkittiin VIF (variance inflation factors) -menetelmällä ja GLM (generalized linear mixed models) -mallinnuksella tutkittiin säämuuttujien ja pesintä menestyksen suhteita. Merkitsevimmät muuttujat todettiin niiden AIC_c -arvojen perusteella. Tämän lisäksi tein samat laskelmat ilman jakoa koe- ja kontrollialueisiin saadakseni alueelta kokonaiskuvan säätilojen vaikutuksesta populaatioon. Laskin myös ArcGis karttaohjelmaa käyttäen erilaisten maankäyttömuotojen verrannollisia vaikutuksia sääksipopulaation pesimistiheyteen ja vertasin niitä keskenään koe- ja kontrollialueella.

Lisäravinnon tarjonnalla ei ollut merkitystä ravintoaltaan lähellä pesivien sääksiparien pesintämenestykseen verrattuna kontrollialueen lintuihin. Keskimäärin yhtäläinen määrä poikasia pesää kohti lähti maailmalle molemmilta alueilta sääoloista riippumatta. Sääoloilla oli kuitenkin jonkinlaisia vaikutuksia pesinnän onnistumiseen, sillä kootusta säädatasta käy ilmi heikompia pesintämenestyslukuja esim. myrskyisinä, sateisina ja kyminä kesinä. Aineistosta johdetut merkitsevyysarvot jäävät kuitenkin varsin alhaisiksi. Ainoastaan kolmen päivän myrskyjen vaikutus oli lievästi suurempi merkitsevyysarvoltaan kuin nollamalli. Syyksi matalaan säätilojen vaikutukseen voidaan olettaa alueen vesistöjen suojaisuutta ja kalaisuutta, sekä suomalaista rantametsien käyttöä, joka takaa tuulen- ja näkösuojan sääksen suosimiin lahtiin ja poukamiin. Sääksen pesinnälle haitallisimmiksi säätyypeiksi osoittautuivat pitkät myrskyiset jaksot (≥ 7 m/s tuuli), sekä sateiset kesät. Kalasääsken pesintätiheyden todettiin olevan huomattavasti suurempi koealueella kuin kontrollialueella tutkittaessa alueiden kokonaisalaa. Lisäksi erojen todettiin kasvavan tutkittaessa pesimiskelpoisten metsien määrää. Tällöin pesintätiheyden todettiin olevan miltei nelinkertainen koealueella verrattuna kontrolliin. Saalistukseen sopivia vesistöjä tutkittaessa eron todettiin olevan 1.5 kertainen. Kalasääski näyttää hyötyvän lisäruokinnasta kasvaneen pesintätiheyden ja sen myötä suuremman alueellisen poikastuoton kautta.

Avainsanat – Nyckelord – Keywords
pesintämenestys, kalasääski, sääksi, Pandion haliaetus, sää, säästä riippuva, sään vaikutus, poikanen, poikastuotto

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Table of Contents

1. Introduction

Supplementary feeding is a common practice in many modern cases of nature conservation and species revival projects. Also in game management supplementary feeding has long traditions (Nummi & Väänänen 2013). The population of an endangered species is often given extra nourishment to maintain population stability, grow back to its previous size or survive over hard times, nature calamities or human impact. In cases in which the species in question is willing to accept supplementary food (often in a form of scavenging) the results of the projects have been promising. Often in a matter of decades the population of the endangered species has been stabilized and in some cases, has started to grow larger again. Even though supplementary feeding has its good sides it also has its critics. It has been accused of being unsustainable, non–natural and not being a cure to the real problem.

This study deals with the question: ”In what way supplementary feeding effects the reproduction of osprey, *Pandion haliaetus*?” In the past decades world has witnessed the revival of many endangered raptor species. During the 1950's, 60's and 70's many animal species suffered from the increased discharge amounts of agriculture and industry alike. Among these harmful substances were DDT (dichloro-diphenyl-trichloroethane) and PCBs (polychlorinated biphenyls), which affect the egg shell thickness of many raptors. Also in mammals DDT and other organochlorines have been shown to have xenoestrogenic activity. They are chemically similar enough to estrogen to trigger hormonal responses in animals and damage the reproductive system and reduce reproductive success. After the problem of discharges had been identified agriculture's emissions were cut by legislation and many raptor species where added to revival projects, that included e.g. habitat preservation, nest building and supplementary feeding (Kirschbaum & Watkins 2000). One of those raptors was the osprey.

Osprey is an interesting study subject due to its adaptable nature. It can survive and prosper in many different habitats on wetlands, sea shores and lakes. Thanks to its resilience and fishing skills the species is also a cosmopolite, found in all continents except the Antarctic (Saurola 1993; Kirschbaum & Watkins 2000). Due to its large distribution, it is also very thoroughly studied species. Its habitats, fishing success, nesting ecology and even tolerance to climate change has been surveyed. In this study I want to open one new chapter in to the data bank of this raptor.

Ospreys are known to utilize fish farms as supplement to their diet, causing economic losses to the farmers. These losses have been documented (Häkkinen & Jokinen 1974; Karevaara 1998;

Savolainen et al. 2012) but the effects of this supplementary feeding on the ecology of the raptor have not yet been analyzed. Osprey is an efficient and capable predator also in the wild. Does this opportunity provide them with something that the natural environment lacks or are they only after an easy food?

Weather variables have been shown to have an effect on ospreys' success in catching prey. Wind velocity, rain and light conditions have all been researched and seen as detriment for normal breeding success rate (Grubb 1977; Heikura 1977; Machmer & Ydenberg 1990; Steeger et al.1991; Karevaara 1998; Castellanos & Rivera 2007). What kind of effects on the osprey population and their reproduction does the supplementary feeding have and how does it combine with weather patterns?

This study was conducted on an old fish farm in Southern Finland, that about two decades ago was turned into an osprey supplementary feeding pond by local conservationists. Nowadays there is one feeding pond, several reservoirs for prey fish and a booming nature tourism business built around the osprey pond. This place gives us the opportunity to examine this cosmopolite raptor, the effects that supplementary feeding has on its breeding success, how do weather variables influence the population's reproduction, what kind of losses the osprey induces to the feeding area and how a tourism based nature conservation works for osprey.

2. Literature and theory

2.1. *Osprey*

The osprey is a large fish eating diurnal bird of prey. They belong to the order of Falconiformes and the family of Accipitridae (Kirschbaum & Watkins 2000). They are the only member of their genus, Pandion, but a very successful one. They are a cosmopolitan species found in all continents except the Antarctic and nests in all except South-America, where they are found only wintering. They are the second most widely distributed raptor species after the Peregrine Falcon *(Falco peregrinus)* (Zachos & Schmoelcke 2006) and have adapted to habitats from southern coastal regions of Australia to inland lakes of North-Alaska (Bull & Farrand 1987; Hume 2002). They have dispersed to some of the bigger islands North-East of Australia, such as Bismark islands, Salomon

Islands and New Caledonia and fossil remains of adults and juveniles have been found as far out as from Tonga (Steadman 2006). Regions where ospreys are particularly abundant include Scandinavia and the Chesapeake Bay region of the United States. (Poole 1989; Steidl 1991; Poole 1994; Poole et al. 2002)

2.1.1. Characteristics

Osprey has a length between 50 and 66 cm, a wingspan between 127 and 180 cm and they weigh between 1.5 and 2 kg (Ferguson-Lees & Christie 2001). The smallest North American males can weigh just 1.2–1.6 kg (Poole 1994). They are brown and white in color, their underside and head being mostly white, and their upper side being glossy brown. They have a dark eye mask and a dark breast band, although this is more prominent in females. The bill is black and the feet are white with black talons. A short tail and long, narrow wings with four long, finger-like feathers, and a shorter fifth, give it a very distinctive appearance.

The appearance of the sexes is fairly similar, but the adult male can be distinguished from the female by its slimmer body and narrower wings. The breast band of the male is also weaker than that of the female, or is non-existent, and the underwing coverts of the male are more uniformly pale (Forsman 2008). Juvenile ospreys resemble adults, but have a more speckled appearance (Kirschbaum & Watkins 2000). The young also have an orange-red iris, easy to distinguish from the yellow iris typical for adults. Juvenile plumage is replaced by adult plumage by 18 months of age (Poole 1989; Poole 1994).

Ospreys' world population of 25,000–30,000 pairs (Hagemeijer & Blair 1997) consists of four different subspecies, which are separated by geographic region: *Pandion haliaetus carolinensis* breeds in North America and the Caribbean, and winters in South America. *P.h. haliaetus* breeds in the Palearctic regions of Europe, North Africa and in Asia, north of the Himalaya) and winters in South Africa, India and the East Indies. *P.h. ridgwayi* resides in the Caribbean, with a range that extends from the Bahamas and Cuba to southeast Mexico and Belize. The fourth subspecies, *P.h. leucocephalus* inhabits Australia and some islands of the southwest Pacific (Kirschbaum & Watkins 2000). The four subspecies display some morphological variations by region; tropical and subtropical populations being smaller than those breeding at higher latitudes. They also show some fluctuation in size and color. *P.h. haliaetus* and *P.h. carolinensis* are the largest and darkest subspecies. *P.h.ridgwayi* is about the same size as *carolinensis,* but is paler on the head and breast. *P.h. cristatus* is the smallest subspecies, with a dark necklace and pale crown (Poole 1994).

Though the ospreys are good in adaptation, they eat only fish. Some rare sightings of osprey snatching ducklings, birds, voles, snakes, salamanders or frogs have been recorded (Goenka 1985; Kirschbaum & Watkins 2000; Poole et al. 2002; Blinn et al. 2006), but these occasions are minimal. Osprey’s diet consists 99% of fish (Evans 1982; Kirschbaum & Watkins 2000). That is about as far specialization goes with this generalist. Osprey fishes prey, big or small, regardless of prey species, equally in lakes, rivers and ponds, as well as at sea. Locally, only 2 or 3 most common prey species may dominate the osprey's diet in a given area (Poole 1989; Poole et al. 2002). One of the key reasons to why they have such a wide global distribution is that they are able to live almost anywhere where there are safe nest sites and shallow water with abundant fish.

Nests are generally found within 3 to 5 km of a water body (Poole 1989). Nest sites are selected to structures that can support a bulky nest and that give shelter from ground-based predators. Historically ospreys have selected tall even topped trees and cliffs as nesting places, but urban age and industry have reduced these traditional nest sites, providing, however, other sort of sturdy bases, such as power poles, duck blinds, communication towers, buildings and even billboards. Even still, ospreys prefer their nest to be in places either difficult to climb or surrounded by water (Kirschbaum & Watkins 2000).

Osprey catches its prey in a unique way for a raptor. They hove in the air till they spot the prey. Then dive through the air, plunging feet first into the water and catching the prey. In the last moment before hitting the water surface the osprey stretches its feet, claws wide open, just in front of its head to maximize the change to catch the fish. This way of fishing allows the osprey to catch fishes from much deeper than other hawks and eagles that only snatch them from the water surface (Poole et al. 2002). Average prey fish of other fish eating Accipitriformes swim at around 20 cm below surface level, where an osprey with its plunge can catch a fish as deep as one meter. After catching the fish osprey uses strong, horizontal wing beats to lift itself and its prey from the water. Once airborne, they rearrange the fish in their feet, carrying it with one foot in front of the other so that the fish is facing forward. The catch is then usually taken to a perch, often near the nest, to eat. The male, responsible of the catch of the whole brood usually eats at least a part of the fish before delivering the rest to the female and chicks (Kirschbaum & Watkins 2000; Poole et al. 2002).

These fishing abilities require some sophisticated adaptations in the bird's build. Ospreys have been known to exhibit great joint flexibility. Wings are long and flexible to many positions and the legs allow a good grip of a slippery fish. Many structural features tell that osprey has been on a fish diet for a long time. The legs are long and featherless. The skin of the feet is covered on the sole side with sharp, spike like nodules, called spicules, to allow a firmer grip. Also its outer front toe bends downwards to allow the osprey to grab the fish from both sides with a firm two toe grip. Talons are long and sickle shape equipped with backwards facing scales. Because of its submerging preying habits, osprey has also developed surprisingly advanced rump grease gland to support the plumage with sufficient greasing and making it water resistant. The species also doesn't develop a brood patch at all, since they dive into water daily, and unlike most other raptors they are able to close their nostrils with efficient nasal valves (Kirschbaum & Watkins 2000).

Osprey’s word population is distributed in all continents, excluding the Antarctic. Nesting activities are centralized to the Northern Hemisphere, where osprey reproduces from Alaska to Newfoundland in North America, Ireland to Scandinavia and the shores of White Sea in Russia and through Asia on lake shores and rivers in the southern half of Russia and also in Kazakhstan and Mongolia. During the cold winters of the Northern Hemisphere the populations migrate to South America, Africa, and Asia’s southern shores. The sedentary populations of Australia and small islands of the Caribbean Sea and West Pacific Ocean don’t migrate. They breed and winter in the same location since they inhabit islands surrounded by vast oceans (Kirschbaum & Watkins 2000).

Ospreys’ key of success and the reason for its large distribution is its ability to use a vast variety of ecosystems and prey. Lakes, rivers, ponds and ocean shores are equally suited for its use. Fishes of all sort include in its menu. Prey size varies from little under 100 g to over 1,000 g. They are also adapted to using very different nest sites around the world from old forests, to marshes, cliffs, and even deserts. Only thing common about the nests is that they all situate on the highest point of the surrounding ecosystem, with a good view and easy take-off and landing. Most important thing is that fishing waters have to be nearby. If there is enough prey, sometimes even colonies of a few hundred individuals can be formed (Saurola 1993; Kirschbaum & Watkins 2000; Poole et al. 2002).

European osprey population is approximately 5,000 pairs (Hagemeijer & Blair 1997). Out of these, approximately 1,200 pairs nest in Finland (Valkama, Vepsäläinen, & Lehikoinen 2011). The ospreys start their migration to the North from their southern wintering areas all around Africa on March, arriving to Scandinavia on April, just when the ice cover starts to reveal waters for fishing. They are day migrators, but can also travel during night time if the conditions are favorable.

The males are the first to arrive to their nests. Ospreys are monogamous and usually also show nest site fidelity, so the male starts to repair the nest after arrival and wait for the female. Rare occasions of polygyny have been recorded to occur in cases where nest sites are close enough together that a male can defend two nests (Poole 1994). When this happens, the first nest usually experiences higher reproductive success than the second because the male devotes more resources to prior. Males start to perform display flights over the nest immediately after arrival to inform the other males that the nest is taken and also to call out for a mate (Kirschbaum & Watkins 2000). When the female arrives, the male offers her fishes as welcoming gifts. After the female accepts him the pair fixes the nest together and starts to mate. Both sexes collect material for the nest, but the female does most of the arranging of materials at the nest. Osprey's nest is typically constructed of sticks that the male crack from tree tops and lined with softer materials such as seaweed, kelp, grasses or cardboard. Nowadays also a collection of human produced litter can be found used as nest material (Poole 1989; Poole 1994). Mating is repeated several times a day during the whole period of egg laying. This is for the male to insure his paternity. The female lays usually 3 eggs (sometimes only one or two, rarely four) in the end of April and incubation lasts about five weeks. Chicks hatch out in Southern Finland in the beginning of June and in North Finland in late June (Saurola 2006). Newly hatched osprey chicks are covered in white down with brown streaks on the face, back, and wings. Osprey females don't leave the nest for fishing. Instead they remain to shelter and protect the chick, where it is the males who hunt for the whole brood. At about the age of 10 days the hatchling down is replaced by charcoal-colored down. Feathers further begin to replace the darker down at approximately two weeks and by the age of one month the chicks have reached 70% to 80% of the adult size (Kirschbaum & Watkins 2000).

First juveniles of Southern Finland leave their nests already in mid-July at the age of 7–8 weeks, but they often stay near the nest till mid-August (Poole 1989; Saurola 1993; Poole 1994; Kirschbaum & Watkins 2000). The juveniles start to practice fishing after leaving the nest, but are still mainly relying on their parents' food service from two to eight weeks, until the beginning of migration. Out of those that start their first autumn migration, half die during their first year (Saurola 1993). After their first year their changes increase significantly, since the adult's annual survival rate is approximately 80–90% (Poole et al. 2002).

Ospreys migrate alone. Autumn migration is characteristically slower than spring migration, when adults hurry to their designated old nests. Especially the young migrate slowly during their first few years. They might stay in Africa or stop at the Mediterranean. Only on their second year they migrate all the way to Scandinavia again, but don't necessarily nest yet. Second year of the young is usually spent on finding a territory, finding a mate and building a nest. After practicing they finally are ready to reproduce on their third summer. If all goes well they’ll have an average of 15–20 years to reproduce during their relatively long life time. The oldest known osprey was a 25 years old American male (Kirschbaum & Watkins 2000).

2.1.2. History of persecution and natural disasters

Osprey is the logo bird of The International Centre for Birds of Prey (ICBP) for obvious reason. Its cosmopolitan status makes it recognizable globally and because of its threatened past, during the 20th century, it is an easy icon. Some forty years ago, it seemed as ospreys were on their way for certain extinction. Accumulation of environmental toxins, destruction of habitats and persecution were rapidly decreasing their numbers still in the 70's. Nowadays osprey serves as a good logo also as to what was done for its revival. Environmental concern and awareness were increased, laws to prohibit the use of environmental toxins and restrict raptor hunts were laid down (Kirschbaum & Watkins 2000) and destruction of nature was monitored, regulated and prevented more vigorously. Ospreys’ population growth was supported also by more concrete manners such as building of artificial nest platforms to regionally replace destroyed or cut old growth forests.

Ospreys were driven to extinction in Central Europe in the end of 19th century. Some remained nesting in Scotland till 1916, but were not seen after that (Poole 1989). Large scale persecution ravaged the population in the end of 19th century and in the beginning of 20th century (Zachos & Schmoelcke 2006). Ospreys were hunted because they were seen as a threat to fish stocks that were used as a source of human food (Kirschbaum & Watkins 2000). Ospreys were considered as vermin at the time as they ate trout *(Genus: Oncorhynchus, Salmo and Salvelinus)* and salmon *(Salmonidae)*, thus being routinely shot by gamekeepers and sportsmen. Recent studies have shown, however, that ospreys actually take a very small portion of all the fish harvested and are not a serious competitor for commercial or recreational fishing (Poole 1989). Häkkinen (1977) discovered that the annual fish consumption of the Finnish osprey population was 108,000–120,000 kg of fish, which was a mere 0.6% of the contemporary commercial catch. Häkkinen (1977) further states that if we consider the fact that ospreys' utilize smaller prey fishes than we do, they might actually even be improving the fish stocks for our benefit, making our preferred prey fish more abundant in the lake ecosystem. In the end of 19th century cutting of old forests for agricultural purposes led to the destruction of their nesting habitats. Even today the paper industry and large scale loggings are the biggest threat to osprey nest sites and reproduction (Saurola 1997). Industrial pollution, increasing rapidly in the beginning of the 20th century, meant that water quality was low and fish stocks declined. Fish were scarcer and waters dimmer. Also the fashion for specimen collecting, taxidermy, and in particular egg collecting, a popular hobby in the late 19th century, greatly reduced breeding success in the already declining population (Kirschbaum & Watkins 2000). There was then a short recovery period before another decline from the 1950s to 1970s (Saurola 1997), caused by a new threat. A novel insecticide called DDT (dichlorodiphenyltrichloroethane) was introduced to the pest-ridden western agriculture as the saving grace in 1939. It gained huge popularity and was considered saving many lives during the Second World War and after by killing malaria spreading mosquitoes and potato beetles (van den Berg 2008). However, the after effects of DDT use and many of its contemporary pesticides and toxins (other organochlorines and PCBs) were not thoroughly investigated at the time, which led to a worldwide natural disaster. DDT accumulates to the animals that eat it and with its vast uncontrolled use, DDT started to build up in the food chain. This led to many birds of prey laying thin shelled eggs that broke easily (EPA 1975). Even the incubating mother's weight was enough to break the eggs and so the buildup of DDT reduced breeding success rapidly. Due to DDT's interference with the birds calcium metabolism and the ongoing persecution, the osprey populations drastically declined in many parts of the world in 1950s and 1960s (Ames 1966; Poole 1989; Saurola 1997; Poole et al. 2002).

2.1.3. Protection movement

Early governmental concern about DDT's possible adverse to nature rose as early as in the 1940's among US scientist and they started expressing estimates of its associated hazards. In the 1950's and 1960's the U.S. Department of Agriculture, the federal agency with responsibility of regulating pesticides at the time, began regulating many of its uses. At the same time (1955) World Health

Organization (WHO) rallied a program to eradicate malaria worldwide, relying largely on DDT (WHO 2008). The initially quite successful program, however, turned eventually against itself. It is believed that DDT's widespread agricultural use lead to resistant insect populations and, combined with communal problems in the developing countries, such as lack of funding, poverty, civil unrest and increased irrigation, eventually partly or even completely reversed the early benefits of DDT use (Greenwood & Mutabingwa 2002; Keiser. et al. 2005). The eradication period ended in 1969 and was replaced by long-term disease control strategy. Even though WHO's eradication plan did not achieve its ultimate objective, it did manage to eliminate the parasite in North America, Europe, the former Soviet Union, all Caribbean islands (except Hispaniola), and Taiwan (Sadasivaiah, Tozan & Breman 2007; WHO 2008) and thus minimizing the risk of disease for about 700 million persons.

With international concern and interest on the issue and with the suggestion of the editor of the New Yorker, William Shawn, the popular naturalist-author Rachel Carson took up the issue of DDT. Her project lead to the publishing of her hit novel Silent Spring in 1962. The book argued that pesticides, including DDT, were poisoning both wildlife and the environment and were also endangering human health, resulting in an impact completely unpredictable to the natural world as we know it (Stockholm Convention 2008). Carson's book efficiently played with fears of the end of days and human made apocalypse but even though it was stretching the boundaries of scientific truth it was a best-seller at its time and launched the start of the modern environmental movement in the United States (Greenberg 1963). One year after its appearance and the rising public demand for action and restriction of the use of DDT and other toxins, President Kennedy ordered his Science Advisory Committee to investigate Carson's claims. The committees report gave quite thorough-going vindication of them, however, refusing the general public's eradication demands of pesticide use but proposing a controlled phase-out reduction of persistent toxic pesticides (Greenberg 1963). Given the roaring public antipathy and the governmental concern successfully provoked by Carson's book, a group of scientists and lawyer founded the Environmental Defense Fund (EDF) on 1967, which specific goal was to win a ban on DDT. EDF's continuous efforts partly resulted in DDT ban in USA in 1972 (Sadasivaiah, Tozan & Breman 2007).

Large part of the countries of Europe followed USA's lead in banning the agricultural use of DDT in the 1970s and 80s. The number of countries banning or restricting DDT use has been on a steady rise ever since, mainly because of nature protectionists' concern and international pressure by the west. The Stockholm Convention on persistent organic pollutants (POPs) is so far the biggest international environmental treaty on the issue. First signed on 2001 and taking effect on 2004 it has been ratified by 179 countries with the aim to eliminate or restrict the production and use of POPs (Stockholm Convention 2013). Though it is not yet ratified by countries like Malaysia, Uzbekistan, South-Sudan, Iraq, Italy, Israel and the United States, it is still a valuable platform for international discussion on the issue of POPs. The Convention has agreed to allow the use of DDT in certain cases, such as humanitarian aid in epidemic and vector control. However, agricultural use is strictly banned as affairs stand (Stockholm Convention 2013).

Currently DDT is produced only by three countries in the world; India, China and The Democratic Peoples' Republic of Korea. India and China produce it mainly for export to the vector control needs of African countries (allowed under the Stockholm Convention), but recent information indicate that Korea DPR produces about 160 tons of DDT per year for agricultural purposes (i.e. not acceptable under the Stockholm Convention) and only small quantities for vector control (Stockholm Convention 2013).

2.1.4. Slow path to recovery

After the ban of DDT and start of protection measures on osprey, the population began a long recovery process. With the revitalization and artificial nest projects the ospreys had regained their lost nesting habitats at least partly, but the environmental toxins leaked to nature during the past decades remained as an impediment to their fast recovery for a long time. DDT and other organochlorides have a very long half-life time. Depending on the soil conditions DDT is estimated to have a half-life from 2 to 15 years (Augustijn-Beckers et al. 1994). Routes of degradation usually take a long time in the wild and breakdown products in the soil environment (e.g. DDE and DDD or dichloro-diphenyl-dichloroethylene and dichloro-diphenyl-dichloroethane) are also highly persistent and have similar chemical and physical properties (WHO a 1989). Even with DDT banned in most parts of the world its effects didn't disappear overnight. In water environment DDT's half-life is considerably shorter. Reported half-life times are 56 days in lake water and 28 days in river water (ETN 2013). However, within this time frame aquatic organisms are able and readily take up DDT particles from the water and store them and their metabolites into their system, thus starting the process of bioaccumulation of DDT and DDE to the top predators in the higher trophic levels.

When DDT enters the system of a living animal it metabolizes into DDE. It is DDE per se that is thought to cause damage to the eggshell (WHO b 1989). Although the exact physiological mechanism(s) for DDE to influence the birds calcium metabolism during ovulation still remain unclear and whether other chemical compounds or factors play a role in the outcome of the effects is not certain, there still is a clear inverse correlation between DDE in raptor eggs and eggshell thickness (Lincer 1975). Experimental studies have shown that dietary exposures to DDT/DDE/DDD are associated with eggshell thinning and breakage in wild birds including the American kestrel *(Falco sparverius)* (Porter & Wiemeyer 1969), the mallard *(Anas platyrhynchus)* (Heath et al. 1969; Risebrough & Anderson 1975; Vangilder & Peterie 1980), the black duck (*Anas rubripes)* (Longcore et al. 1971), the Japanese quail *(Coturnix coturnix japonica)* (Kenny et al. 1972), the bobwhite quail *(Colinus virginianus)* (Wilson et al. 1973) the Ring-necked turtle-doves *(Streptopelia risoria)* (Peakall 1970; Haegele & Hudson 1973; Peakall et al. 1975) and the barn owl *(Tyto alba)* (Mendenhall et al. 1983). These experimental results have revised that the field observations of eggshell thinning and reductions in wild raptor populations are associated with releases of DDT. The raptors body stores DDE mainly in the adipose tissue in a relatively stable form. This is, if the individual is healthy. However, if the body starts to use the fat as sustenance, also the DDE particles are released to the system. This is thought to be the reason why egg producing females, under a physical stress, release the stored DDE from their fat, thus letting it influence the nascent eggs. Prospective mechanisms of eggshell thinning in birds have been widely studied and reviewed (Cooke 1973; EPA 1975; Peakall et al. 1975; WHO b 1989; Lundholm 1997). The leading hypothesis for DDE-induced thinning involves an inhibition by p,p'-DDE (but not by o,p'-DDE or DDT or DDD isomers) of prostaglandin synthesis in the shell gland mucosa (Lundholm 1997). Overall, there is still some question as to the primary mechanism and reviews suggest that these may differ between bird species, environmental conditions or physiological state for a given species. The complete picture of what mechanisms and to which species cause eggshell thinning remains unfinished.

By the mid-1970s, osprey populations started to recover (Saurola 1997) as DDT discharges started slowly to degrade. Even so, the remaining residues still posed a threat to the egg shells for many years to come. In the United States, Maryland's median DDE concentration values saw no significant decline in osprey eggs in 1973–1986. The values surpassed the values indicated for 10% egg shell thinning, but were below the assumed values for threatening a stable population (1.0 young per active nest). Also the values of DDD and DDT in osprey eggs in Massachusetts and Virginia in 1986–1987 were similar to those of 1970s for both states (Audet et al. 1992).

Studies comparing the nesting success on the Atlantic coast of USA 1987–1988 indicate that on average 69 % of the laid eggs hatched. In certain places with suspected higher environmental contaminant rates, such as the Delaware Bay, 50% of the eggs laid failed (Steidl et al. 1991). The study suggests that the differences of nesting success and unhatched eggs might be due to higher regional toxin values.

Another study from Delaware Bay area (Clark et al. 2001) compares DDE values of 1989 and 1998. As time had passed, this study states more promising results, narrating that DDE contaminants decreased in osprey eggs from 1.2–3.2 ppm (in 1989) to 0.7–1.2 ppm (in 1998). The same trend was visible also in the ospreys' prey fishes. DDE values decreased from 0.05–0.69 ppm in 1989 to 0.03–0.13 ppm in 1998. These improvements in local organochlorine values reflected improved nest success in the Delaware Bay, and the nesting populations in the study areas increased approximately 200% in those ten years. National survey reveals that USA's osprey population was recorded to be 8,000 nesting pairs in 1981, but with a steady increase it was recorded again in 1994 to be 14,246 nesting pairs (Houghton & Rymon 1997), making it a 178% increase in population in 13 years.

In Europe eggshell thickness also first thinned out because of the accumulation of organochlorides. In one study with one of the longest timelines in Europe; Weber, Schmidt and Hadrich (2003) studied 338 osprey egg samples collected in Germany between 1853 and 1997. The shell index of the eggs collected from 1959 to 1983 (during DDT use and residues) showed signs of average 9% reduce in eggshell thickness compared to samples from 1853 to 1933. The values of the samples collected during the heaviest DDT usage era (four clutches collected from 1959 to 1964) showed an even greater reduction of shell index of 14%. This level of thinning already starts to be threatening to the embryo inside the egg. No raptor population exhibiting 18% (equals approximately 6 ppm of DDT) or more eggshell-thinning has been able to maintain stable self-perpetuating populations (Lincer 1975). Most recent samples from Germany indicate that the current effect of organochlorides on osprey nesting success is low and also the egg shell thickness has returned to almost same values as pre-DDT (Weber et al. 2003).

Ospreys' fish diet might have actually saved them from even larger population decline. An Australian study (Falkenberg et al. 1994) investigated the degree of organochlorine pesticide contamination levels in peregrine falcon, osprey and white-bellied sea eagle *(Haliaeetus leucogaster)*. Levels of residue were obtained from eggs and tissue with the measurements of egg shell thickness. Residue levels in this study were found from low to moderate, but what is interesting is the divergence between species. Out of these three, only osprey feeds solely on fish. Highest DDT levels were found in the peregrine falcon (mean 1.85 mg kg^{-1} followed by white bellied sea eagle with (mean 1.07 mg kg^{-1}) and osprey (mean 0.11 mg kg^{-1} respectively). This means that the peregrine falcon had almost seventeen times more DDT concentrated per kg than the osprey. Both of them are birds of prey, living in the same area. The answer might be found in their diet. Osprey is a 99% fish eater, whereas peregrine falcon is a bird eater. When the team researched for DDT residues in other bird species in the area, levels of concern were found in several prey species commonly found in the diet of white-bellied sea eagle and peregrine falcon, particularly in feral pigeons (37.46 mg kg^{-1}). This level is well above those known to cause reproductive failure in falcons (15–20 mg/kg) (Peakall et al. 1990). Pigeons frequently feed in agricultural fields, heavily spayed with DDT at the time, thus resulting in very high levels of metabolites. As a result peregrine falcon declined whereas the osprey, whose DDT intake had to be a result of diversion from the fields to rivers with leaching and metabolizing through macro plankton to its prey fishes, remained relatively healthy and productive compared to its Falconidae cousin.

Currently the world’s osprey populations have principally revived after the banning of DDT and are now reaching historic levels. Installation of artificial nest structures, hatching projects and new habitat created by reservoirs have allowed osprey populations to increase and expand their range. (Poole 1989; Poole et al. 2002).

2.2. Fish farming industry

Osprey has been known of being very adaptable and opportunistic raptor, and human bred fish populations are no exception. Already in the 1600’s ospreys preyed on carp ponds of Central Europe (YLE 2013). Modern studies tell that the osprey has also learned to utilize modern fish farms as food source (Häkkinen & Jokinen 1974). Actual economic losses, however, are limited to fish farms. As Häkkinen (1977) and Poole (1989) have shown, ospreys’ uptake plays a small role in the other forms of economic and recreational fisheries. However, with the adverse conditions economic losses on fish farming institutions can raise up to 4% of total production.

One of the most extreme examples is the (nowadays closed) fish farm of Virolaistenlahti. This farm was exceptional and ideal for osprey foraging in many ways. It was bay, an open water area, enclosed only by a fence from the bigger lake Längelmävesi. Often described as "The world's best osprey feeding area" or "Osprey heaven" by the locals, foreign visitors and scientists (Koivu 2013), this 2.5 ha small gulf was very shallow with very few employees to disturb the birds and with practically no sky nets, wires or other mechanic impediments, allowing the local osprey population to feast upon the rainbow trout's (*Oncorhynchus mykiss*) bread there (Häkkinen & Jokinen 1974). On top of this, Virolaistenlahti is situated in one of the most densely populated osprey breeding grounds in Finland (Häkkinen & Jokinen 1974; Saurola 1993). Contemporary studies tell of over 5,800 fish annual uptake by osprey in Virolaistenlahti. This equaled 1,436 kg of fish (Häkkinen & Jokinen 1974). In 2012, the price paid to the farmer for a kilo of rainbow trout was 3.20 € in Finland respectively (Nylander 2013). However, the trouts hunted by osprey are still small (mean 250 g) (Häkkinen & Jokinen 1974). To calculate more accurate immediate economic losses one thus has to take into consideration the loss of an individual, potentially sold in a few years' time. Rainbow trouts are usually sold when they have gained 0.5–2 kg (UNWTO (1). 2013). This would mean that 5,800 fishes weighing approximately 1.25 kg would be worth of 23,200 € in modern market. In 1986 when the rainbow trout's price was at its highest in recent history (7.90 € / kg) (Nylander 2013) a forfeiture of this scale would have resulted in 57,300 € annual losses. Whitefish is one of the most expensive farmed fish in the modern market (6.73 € / kg to farmer) (Nylander 2013). At the same time it is also one of the most osprey intriguing fish species, because of its restless movements and school dynamics (Koivu 2013). If the farm in question would have been producing whitefish they might have ended up with 25,400 € annual loss in 2012, taking into consideration that whitefish is sold when it reaches 450–800 g and over (Setälä et al. 2007). There is little question why Virolaistenlahti fish farm is no longer in operating. One must take into consideration, however, that; 1. this fish farm was an exceptionally good hunting area in a very densely populated nesting area; 2. other fish eating birds like goosanders, mergansers and gulls played their part in the final uptake total, and 3. that in more common fish farms with better protection and less ospreys the losses would have been much more moderate. Even the authors of the Virolaistenlahti research; Häkkinen and Jokinen (1974) stated after these results that with such a large predation pressure of 3–4 % of the whole number of fishes in the pool, Virolaistenlahti "has to be considered as a unique exception, one that cannot be generalized elsewhere".

In the wild, ospreys prey upon fishes ranging from 100 g to 1,000 g (Karevaara 1998). In

Virolaistenlahti fish farm ospreys' preyed on average 250 g fishes (Häkkinen & Jokinen 1974). This means that ospreys eat mainly one year old trout's. The ospreys do not hunt the bigger individuals to be sold or further used for breeding. However, they do tend to sometimes scratch and injure the nearby fishes when striking, resulting in scars, sales unusable fish, mold infections and even death (Koivu 2013). Further economic impact comes with the pre-emptive work of placing nets, keeping surveillance and maintaining other impediments. Considering ospreys protected status many governments have decided to partially compensate the economic losses caused by osprey to the farmers.

Karevaara (1998) studied the hunting behavior of ospreys at Huutijärvi fish farm (center of my study area) during summer and autumn 1995 and in spring 1996. Huutijärvi is situated in the same densely colonialized osprey breeding area in southern Finland as the previous Virolaistenlahti fish farm. Karevaara (1998) recorded 188 successful hunts during incubation period (54 observation days), 860 during nestling period (55 observation days) and 1,316 during fledgling period (38 observation days) on the farm. This total of 2,364 prey fishes was estimated at approximately 1,160 kg of fish. The average prey fish weight 300 g, which means annual losses of 9,500 € in the modern market. Even for whitefish the value would be 10,300 €, on this heavily predated fish farm. Finland produced 11.3 M kg of commercial farmed fish in 2011. Out of which 83% (9.3 M kg.) was farmed on sea areas in net pools (Savolainen et al. 2012) that are osprey safe. Thus, the worst case scenarios stated above are no way related or comparable to modern fish farming industry where the pools and sacks are predator safe.

Karevaara's (1998) findings are interesting for this study because he clearly observed an increase on the number of hunting ospreys recorded at the pond during windy and cloudy weathers. This might indicate that ospreys suffering from impaired weather conditions have a tendency to centralize their hunting to the fish farms' more secure fish stock. This type of behavior is of course easily derived, since the fish ponds don't suffer from the deteriorated hunting conditions during bad weather as much as the open natural waters. The ponds are so small that practically no big waves develop even during stormy wind and the fish can't escape to the deep water during these weather conditions, thus being always available. This leads to the research question of this study: Is the additional nourishment essential to the chicks' survival? This matter will be studied in more detail later, in chapter 3.

Today the Pohtiolampi Osprey Center spends approximately 4,000 € annually (food and maintenance) to feed their visiting ospreys with 1,200–1,800 kg (depending on the year) of assorted B-class rainbow trout. This means approximately 4,000–5,000 prey fishes. This sum is covered with the incomes of the international nature photography tourism. The sum is, however, disparate from modern fish farms with protective nets or even tanks for the smaller, more enticing fish. Pohtiolampi facility focuses their actions to specifically feeding the ospreys so their costs are much more than the average farmers (Koivu 2013).

Ospreys are not dependent on fish farms at any level. They just happen to be enticed by the abnormally dense fish populations of these facilities. Best way to avoid conflicts between ospreys and farmers is to pre-emptively construct the fish farms so that it efficiently prevents the ospreys from hunting. Most used method is to cover the pools with dense lines. If the borders are closed with nets it will stop the gulls and goosanders fishing as well.

2.3. Nature tourism

Tourism is one of the world’s leading global industries contributing to a significant proportion of world production, trade, investments and employment. The number of international tourist arrivals have risen by nearly forty folds from 25 million in 1950 to 980 million in 2011, past 1 billion to 1,035 billion in 2012 (UNWTO 2013 a, b) and is forecasted to exceed 1.8 billion by the year 2030 (UNWTO 2011). Tourism had an estimated turnover of US$ 1,075 billion in 2012 and the business is on steady 4% annual growth (UNWTO 2013 a). Ecotourism is the fastest growing sector of the tourism industry. It had 7% of the market still at 2007, but is estimated soon to take 25% of the global market (CRT 2013). Unfortunately in many areas local nature, infrastructure and traditional sources of livelihood have suffered greatly due to the progress of the tourism industry. Therefore tourism industry has been heavily criticized in the social media as well as in the pages of scientific publications during the past decade for being unsustainable and destructive. Recently the worry for environmental issues of the industry has led to global appreciation of sustainable tourism values and recent studies tell that 96% of the travelers consider the care for the surrounding environment to be part of the hotels or resorts operational responsibilities and that 74.5 % continue saying that the hotels’ environmental policies influence their decision to stay there (CRT 2013).

The overall picture of tourism’s influence on wildlife is not the best it could be. Tourism related activities have been studied to almost always pose a potential or an acute risk to local wildlife. Globally 63 critically endangered and endangered bird species have been reportedly threatened by tourism (Steven & Castley 2013). That is tourism all together, but is ecotourism any more environmentally sustainable than other forms of tourism?

Krüger’s (2005) meta-analysis of 251 ecotourism case studies reviewed that 62.8% of the studies saw ecotourism sustainable. Unfortunately this 62.8% sustainability is not divided equally between continents, countries or biotypes. Krüger (2005) observed that North America had the highest proportion of case studies classified as sustainable (78.6%) and that Asia and South America had been left behind with 40.6% and 42.1%, respectively. The best place for sustainable ecotourism seemed to be temperate forest environment (with 90% sustainable), but particularly fragile ecosystems to ecotourism were found on islands (38.5% sustainable) and on mountain ranges (28.6% sustainable). What is remarkable in the current situation is that only 17.6% of the case studies, subscribed as sustainable, actually made a positive contribution to the local environment and nature. This value can be considered rather low.

Steven et al. (2011) meta-analysis on ecotourism’s effect on local birds is even more alarming read. The analysis of 69 case studies ranging from 1978 to 2010 revealed 61 (88%) studies that had found negative impact on birds including changes in physiology, immediate behavior, abundance and reproductive success. It has to be noted that the studies surveyed by Steven et al. (2011) all dealt with non-motorized nature based recreation such as wildlife viewing, hiking, mountain biking and dog walking. Most of the responses detected in the birds were pretty mundane such as changes in body temperature, heart rate or stress hormone secretion (physiological effects) and changes in foraging, vigilance and evasion (immediate behavior effects). Most of us have encountered these reactions on hikes or walking the dog. Birds can act stressed, run away or even attack the intruder. It is important to understand that prolonged disturbance can have negative effect on the birds, like many of the studies reviewed by Steven et al. (2011) indicate. Responses to nature based tourism can include reduction of reproductive success, number or density of birds, nests build, eggs laid and chicks hatched or fledged (Liddle 1997; Buckley 2004; Müllner et al. 2004; Banks & Bryant 2007; Liley & Sutherland 2007; Cardoni et al. 2008). Namely reduction of reproductive success is the most worrying result reported by Steven et al. (2011). Out of the papers, studying effects on reproductive success (33 papers), 85% found negative effects. What we do learn from this is that most researched birds are sensitive to distraction and that it could be harmful to the community, nest, clutch, or fledglings.

The study of Steven et al. (2011), however, focuses on the negative effects of tourism. Ecotourism can provide the birds with various benefits, such as leftover food, extra nesting places in/on buildings and structures, supplementary food related to hunting tourism, shelter from weather or predation, feeding ponds for fish eaters and nature photography based carrion feeding for large and small birds of prey, not to forget scavengers. We have to base the interaction to a simple win-win-situation requiring the birds' voluntary. Especially if the last condition is met, it is hard to believe that the operations in question would be unprofitable and/or traumatizing for the bird itself.

Unfortunately the voluntary usually only concerns the few charismatic species and only their co-operation is needed in securing sufficient amount of visitors. This is completely manageable in relatively small resorts or protection areas where the visitors don't wander around looking for scenic vistas. However, in places with vast land areas (e.g. National Parks) wandering tourists can produce serious harm to some of the not-so-appealing and sometimes endangered smaller species. Ecotourism can lead to ecosystem degradation if the park management is more concerned about increasing revenues than about the conservation target. If the area is large, it is up to the park management to figure out ways for sustainable use, since most of the visitors are often completely unaware of the harm they incidentally cause to the smaller species of wild life. It is especially because of this unintentional impact that some authors argue that ecotourism cannot be beneficial to conservation (Bednar-Friedl et al. 2012). It seems that also non-motorized natural recreation, such as hiking, climbing and wildlife observation, are harmful to the protected areas combined with the public's unawareness of their risk potential. Once fled bird might not actually return to its nest. Also it might not be able to find food from where it fled to. Stress levels also reduce its foraging time and/or resting time, which results in reduced food intake and increased energy consumption, further unbalancing its survival tactics (Bednar-Friedl et al. 2012). This might again lead to lowered breeding success. Leisure activities can also result in reduction of the overall carrying capacity of the habitat by reduced availability, when some parts of habitat are left completely unused by the birds. In ecotourism case studies, habitat alteration, soil erosion and pollution were noted in almost 50% of unsustainable cases, further followed by consumptive land use by the local community (often left out of the tourism business) (Krüger 2005).

As ecotourism increases national parks face a common and increasingly significant problem of how to combine financing of the park, increasing demand for recreation and the conservation policies for endangered species (Lockwood et al. 2006). Luckily there is also increasing national and international concern on the effectiveness of the parks conservational goals and thus many public authorities have linked the parks funding to international programs (such as the European Union's LIFE projects), making the funding conditional to management effectiveness in the park (Bednar-Friedl et al. 2012).

If entrance fee is added to the park, the visitors might start to think about nature as more of an attraction. They might want to derive benefit from using the park and even change their behavior to noisy, littering and consumptive. However, too small entrance fee doesn't benefit the park's conservational goal (Krüger 2005). The lower the cost, the higher the number of visitors, the smaller the habitat left and the lower the price visitors are willing to pay (Bednar-Friedl et al. 2012). Low entrance fee basically benefits only the tourists as it is. The answer is high enough entrance fee that lowers the amount of visitors, but allows stable income and funding of the parks management plan for better measures of conservation. This is achieved only through active and non-corrupted park management. Also reducing admittance during breeding season should be considered.

One important factor is also information distribution. Simple signs have proven to be one of the most effective and are most recommendable. Very few tourists read long signboards, but most of us have an inbuilt tendency to read warning signs, thus the higher success rate of such signs. It is important to chart key habitats, vulnerable to disturbance within the park and mark them accordingly. Many times the main limiting factor is sustainable breeding areas and those are situated often in the bottom of the valleys. Also trails are often placed to these same valleys, but it might not be the best way for conservation. Huts and fireplaces of course need to be in a sheltering environment with water available, but higher altitude walking trails often have more scenic value and can protect the small wildlife better. With ecotourism increasing at high rates, the question is moreover not whether ecotourism should be allowed but how ecotourism can be steered and redirected such that conservation goals are not jeopardized (Bednar-Friedl et al. 2012).

What is interesting for this study in particular is that most ecotourism case studies show that if the conservation subject/key species is a charismatic bird, the project is highly likely to be environmentally sustainable (80% of the case studies were sustainable) (Krüger 2005). This is best only by charismatic mammals with 81.3% sustainability rate. Even world-wide flagship species (72.2%) can’t best charismatic birds. Osprey falls in both the category of charismatic birds and world-wide flagship species. Also Pohtiolampi falls into many categories of environmental sustainability described earlier. The area is small, the visitors have a short distance to walk from the car park to the observation tower, the trail to the towers is sheltered from osprey in a forest and observation towers have reflective windows allowing the visitors to observe the raptors without disturbing them, no flash is used in photography and the raptors come to the feeding pond willingly but fish prey themselves. The fish excrement is another issue. Water eutrophication by excrements is a problem in the larger commercial fish farms where the fish are fed with more nutriment and are kept in nest sacks from where the excrements freely sink to the bottom. Pohtiolampi pool is excavated to the ground so most of the excrement falls to the bottom from where it is removed every second year to fertilize the nearby field. Some portion of it, however, might be flushed downstream with the current (Koivu 2013).

Osprey is an interesting raptor for the nature tourism industry for many reasons. It is a big charismatic bird of prey, known globally and its way to hunt makes it a dream subject for nature photographers. Other studies suggest that ospreys may be a valuable indicator species for monitoring the long-term health of large rivers, bays and estuaries (Kirschbaum & Watkins 2000), because of their piscivorous lifestyle and their known sensitivity to many contaminants. They are also relatively easily studied because of their conspicuous nests and tolerance for short-term disturbance, such as nest observations by researchers. The presence of ospreys may benefit local economies by boosting ecotourism (Poole 1989; Poole et al. 2002).

3. Research problem and defining the research questions

In this thesis I wanted to further study the relations between osprey breeding ecology and their supplementary feeding. Osprey is an extensively monitored and researched raptor, hence my research questions derive from the following facts.

Weather has been shown in many studies to have an effect on ospreys' success in catching prey. Wind velocity, rain and light conditions have all been researched to be detriments for normal success rate (Grubb 1977; Heikura 1977; Machmer & Ydenberg 1990; Steeger et al.1991; Karevaara 1998; Castellanos & Rivera 2007). There is some variation between different studies where the effects of weather changes have been seen from a small hindrance to severe detriment to the hunt time and success rates. Grubb (1977) recorded that the dive success rate decreasing over 50% when water surface conditions turned from smooth to heavily rippled, whereas Castellanos & Rivera (2007) recorded almost 90% decrease in success rate when wind speeds turned from low to intense (≥7m/s). On the other hand some studies have seen no impact to the hunt at all (Green 1976; Stinson 1987). The above-mentioned studies argue about the significance of the impact of weather. Seemingly it didn't affect the sufficient food intake of a grown up bird in the above-mentioned studies, but could it be harmful to the offspring if unfavorable weather conditions would drag on? At least the fishing times have prolonged with weather conditions worsening (Green 1976; Swensson 1978; Karevaara 1998; Castellanos & Rivera 2007). Ospreys usually have three chicks and since the pecking order dictates the order in which the chicks eat, it might be that weather in certain cases could result in the death of the youngest nestling, even though Grubb (1970), Green (1976) and Stinson (1987) saw no change in the volume of fish brought to the nest. Studies on other species have shown a reduction in nestling growth or parental provisioning in bad weather (see Machmer & Ydenberg 1990). It could be that osprey would be susceptible to weather extremities as well. It has been suggested that also cool weather could result in higher infant mortality (Odsjö & Sondell 1976), however, this should not be the case if all chicks are well fed (Odsjö & Sondell 1976; Poole 1982; Machmer & Ydenberg 1990; Karevaara 1998).

The nestlings are most vulnerable to weather anomalies during their first 35 day (Green 1976; Odsjö & Sondell 1976). During the first weeks after hatching the osprey chicks cannot control their body temperature very well, so their heat maintenance is relying on the females brooding. The average food intake of a nestling is estimated to be approximately 250 g of fish per day (Karevaara

1998). Normal five individuals' osprey family would then consume 1,440 g of fish per day, since the parents are estimated to use about 690 g. Then hunting male eats first and then leaves the female to share the rest with the clutch. Osprey is an efficient predator, usually able to provide sufficient food even to a four chick clutch. However, this ability is argued to be influenced by prey species, hunting area and how experienced hunter the individual is (Swensson 1979; Koivu 2013)

There is a lot of research to be found on ospreys' hunting success and on the reasons resulting to changes in it. In these studies there is also a lot of discussion about the effects of weather anomalies to the success of the nesting, but these effects have not yet been researched. Steeger (1991) has noticed that even though populations would be living in two very different habitats considering prey abundance, the population reproduction doesn't suffer from these differences significantly. Osprey is able to provide its nest with sufficient food within a matter of minutes to few hours (Green 1976; Stinson 1978). However, some extreme and prolonged weather anomalies and stormy summers might limit osprey reproduction success (Odsjö & Sondell 1976; Stinson 1978; Poole 1982). Osprey has been a relevant concern for the conservationists for four decades. Also in my study area an estimated 90% of the pairs nest in artificial nests, provided to replace the old even top pines felled by the forestry industry. Osprey is an adaptable and opportunistic species and has learned how to use fish farming industry for its benefit. On my study area there is a fish farm that has been turned into a supplementary feeding pond by conservationists during the 90's. Now this feeding pond is a local attraction for the osprey and nature tourists alike, and maintenance costs are met with tourism income. I wanted to use this opportunity to study whether the local osprey breeding success is influenced by this supplementary feeding and ecotourism in the area, compared to the control area.

The research questions are the following:

1. Does supplementary feeding influence the ospreys' breeding success?

   Hypothesis: Yes.

2. What are the most difficult weather patterns for ospreys' reproduction?

   Hypothesis: Prolonged storms cause infant mortality.

3. Is the nesting density increased near the feeding area compared to control area?

   Hypothesis: Yes.

4. Material and methods

4.1. Study area

I conducted this study in the lake district of southern Finland. The center of the study area was a small pond (10m x 25m) situated on an old fish farm that has been turned in to a conservational supplementary feeding pond for the osprey from 1995. I defined the study area and control area of circular shape surrounding the facility (61° 26.876’ N, 24° 7.705’ E). The study area is a circle with a radius of 30 km and its center is the prey fish pond of Pohtiolampi Osprey Center. Where the study area ends the control area continues consecutively (see Map 1.). Also the control area has a radius of 30 km, but is considerably larger in size. The size of the study area is 2,827 km² and the control area is 8,482 km².

I defined the study area’s radius based on the knowledge of osprey’s flight distances to the hunting area. Häkkinen and Jokinen (1974) reported that longest distance regularly made by an osprey male to the nearby fish farm of Virolaistenlahti was 19 km. Karevaara (1998) reported travel distances of 3–25 km to Huutijärvi fish farm, which was the predecessor of Pohtiolampi Osprey Center. Juhani Koivu (2013) (the Executive Director of Pohtiolampi Osprey Center) stated that the longest ring controlled travel distance to Pohtiolampi feeding pond was made by a nesting male osprey from 43 km away. He then added that these distances are exceedingly rare and only made during extremely harsh weather conditions and driven by the need of sustenance. Also in the Virolaistenlahti fish farm there has been several ring controls of males coming from approximately 40 km away, but since these sightings do not describe the usual everyday distances made by a hunting osprey, I decided to delimit the study area to 30 km radius from Pohtiolampi Osprey Center, which in my mind describes the realistic maximum distances having any statistical meaning to the survival of the offspring on a bad summer.

4.2. Habitat structure

The study area is dominated by rambling lakes with large open water areas, lots of capes and islands with a lot of shore line, and shallow bays with plenty of prey fish. Osprey has been noted to have better fishing success rate in shallow water and low tide (Castellanos-Vera & Rivera 2007), but they do also fish in deep water (Swenson 1978), thus these vast labyrinthine lakes provide a lot of potential fishing grounds for them. It is of no wonder that this area is and has been historically heavily populated by osprey even to the point that some place names of the area refer to the raptor, for instance Sääksmäki in the southern part of our study area means “Ospreyhill”. There are 632 km^2 of water in our study area alone. On average the lakes around Sääksmäki are 5 m deep with a lot of shallow shorelines of 0.5–2 meter in depth and eutrophic gulfs to host large quantities of prey fish.

I calculated 1,503 km^2 of potential nesting area (relatively undisturbed old growth forests and mires) within the study area. The remaining 679 km^2 are agricultural land, urban areas or otherwise constructed, unfitted for osprey to nest or hunt.

4.3. Brood ecology in study area

The osprey male is usually the first one to arrive to their respective nest in our study area at mid-April (Saurola 1993). Females arrive few weeks later. If their nesting remained undisturbed last years the osprey couple usually occupies the same nest as in the previous years. The pairs copulate in the end of April and first eggs are laid in the first days of May. Ospreys’ incubation time is approximately 36 days (Saurola 1993) in the Fennoscandia. The eggs are laid in few days intervals and they hatch likewise, resulting in a pecking order among the hatchlings. In a bad summer, when food is scarce, the younger chicks are often left without food as the senior eats first his/her mouthful. Ospreys usually lay 2–3 eggs, rarely four or one. First eggs hatch in the study area on 7^{th} of June (Saurola 2006) and after a week the whole clutch has hatched. The nestlings are most vulnerable to weather anomalies during their first 35 days (Green 1976), thus this study monitored specifically these first 35 days. During the first weeks after hatching, osprey chicks can poorly control their body temperature. The female parent thus warms the chicks almost constantly for the first two weeks, continuing to do so even after that during very hot or cool weathers (Poole 1989; Poole 1994; Poole et al. 2002). After about five weeks the female starts to leave the nest more often and for longer times to either hunt or guard the nest from a distance (Green 1976). The osprey defends its nest fiercely against all disturbances, however, short-term visits by man (e.g. ringing of chicks) are tolerated without an attack on the foe or the discarding of the nest (Poole 1989; Poole et al. 2002). The juveniles fledge at approximately the age of 52–55 days (Green 1976; Häkkinen 1977; Saurola 1993), but often stay in the nest or near it for few weeks more, eating and sleeping in the nest. After fledging in mid-July the juveniles stay in Finland till at least mid-August. Most of them gather strength for the migration until late-August or early September, but some remain until early October (Saurola 1993).

4.4. Data collection

I collected the data from the lake areas of Tavastia Proper and Pirkanmaa provinces, in South-Western Finland in 1997–2012. I used the assembled data from Finnish Meteorological Institute (FMI) and Museum of Natural History, University of Helsinki. The former provided me weather data that included daily rainfall, hourly rainfall, hourly wind speed, direction of wind, hourly temperature (day time) and lowest night temperature from three different weather stations within my study area. The latter provided me information from osprey database about sightings and ringing data. This osprey database data was collected from the nests during summers of 1997–2012 and it gave me an overview about the number of chicks ringed, found dead, or that had already left the nest before ringing. Together this data included the whole weather, 397 nest sites and over 1,160 nesting attempts (with chicks hatched) within the study and control areas, among other factors examined (Table 1).

The source of the meteorological information requested from FMI divided between the three weather stations as followed. Tampere-Härmälä weather station provided: daily and hourly rainfall values, hourly temperature (daytime) and lowest night temperature. Tampere-Pirkkala station provided: daily and hourly rainfall values, wind speed, wind direction, hourly temperature (daytime) and lowest night temperature. Tampere-Siilinkari station provided: wind speed, wind direction, hourly temperature (daytime) and lowest night temperature.

The meteorological data was delimited to a time frame from 5th of June till 10th of August. The mean day for the first chick to hatch in the study area was 7th of June, respectively (Saurola 2006). Since the chicks are most vulnerable to extreme weather condition during their first 35 days (Green 1976) I concentrated the observations to this delimited time frame, ending up extrapolating the most significant observation time, from 7th of June till 12th of July. Based on the weather data I then calculated the annual rainfall and temperature values, and the frequency, intensity and length of the storms (wind speed ≥7 m/s) occurred. I thus derived a chart of annual storms in the study area, showing the total amount of stormy days during summer and the duration of individual storms.

Table 1: List of covariates

Covariate:	**Abbreviation:**	**Continuous/Categorical:**
Nest ID number	Int	Continuous
Nest site situated in either study or control area	Study	Categorical (1 = study, 2 = control)
Number of storms lasting two days in a row	Storm2	Continuous
Number of storms lasting three days in a row	Storm3	Continuous
Number of storms lasting over three days in a row	StormOver3	Continuous
Rain sum of the nesting period: Measured in mm.	Rain_sum	Continuous
Temperature: Measured in Celsius.	Temp	Continuous
Year the study was conducted	Year	Continuous
Chick count of the year: Study and control areas' nests combined.	Chicks / Year	Continuous
Average chick count of one nest on that year: Study and control areas' nests combined.	Chicks / Nest	Continuous
Number of inhabited nests with chicks	Nests	Continuous
Rain per day: Average rain fall of one day during the nesting period.	Rain / day	Continuous
Wind speed: Measured in meters / second.	Wind	Continuous
Night temperature: Measured in Celsius.	Night Temp	Continuous
Number of storms: Total = Number of stormy days during nesting season. 1d, 2d, 3d and Over 3d = Number of times a storm of certain length took place during nesting season.	Storms	Continuous
Maximum storm's length: The length of the single longest storm during the nesting season. Measured in days.	Storms MAX d.	Continuous

The 7 m/s or higher wind speeds is seen as a limit for the wind to start seriously complicating ospreys hunts (Machmer & Ydenberg 1990; Castellanos-Vera & Rivera 2007), resulting in “heavily rippled” water surface conditions also mentioned by Grubb (1977). The studies above even suggest that a 3–4 m/s wind already might have some effect in the length of the hunt of an inexperienced adult. Rainy and windy weather break the water surface and temporarily increase washout particles in surface waters, thus decreasing the visibility to the water. Poor visibility to the water, opacity or light conditions are proven to hamper ospreys hunting success and extend hunting time (Ueoka 1974; Grubb 1977; Heikura 1977; Machmer & Ydenberg 1990; Castellanos-Vera & Rivera 2007). I wanted to find out if extended poor weather conditions could impede ospreys hunting to the limit where it would actually be harmful to the youngest chick or the whole clutch, like it is suggested by Odsjö & Sondele (1976), Poole (1982) and Machmer & Ydenberg (1990).

4.5. Statistical analyses

When the statistical data was gathered I created a summary table (Table 2) of all the weather variables and breeding success to see if there would be clear trends of dependence. I then ran the processed data of both Finnish Meteorological Institute and Museum of Natural History in to R (3.0.2.). Continuous covariates included all of the weather variables and response variable was the nestling count. Other factors included the study year, nest ID and position data (study area/control area). Before applying any statistical models I carried out a data preprocessing, following the protocol described in Zuur et al. (2010). I examined the presence of outliers and then searched for continuous covariates in the response using Cleveland dotplot (Cleveland 1993). When the outcome is not binary, outliers may cause overdispersion in a Poisson GLM (Generalized Linear Model) (Hilbe 2011). Collinearity increases the type II errors, i.e. failure to reject the null hypothesis when it is untrue (Zuur et al. 2010). I measured pairwise collinearity with Pearson correlation and assessed the overall collinearity with variance inflation factors (VIF) process. I made scatterplots between each continuous covariate and the response variable to detect the type of relationship.

The versatile weather data, with its many variables, posed an obvious potential for statistical error. I found three pairs of high collinearity within the data set. Rain sum correlated with Rain average and One-day-storms, Temperature with Night temperature and Wind average with Storms. I eliminated one of the two variables in all the cases reaching correlation values over 0.6. Further on, I followed the VIF process by omitting all the variables with value over 3 and dropped four variables. The ones removed where Rain average, One-day-storms, Night temperature and Wind average. I considered rain sum to be more descriptive than daily rain average and One-day-storms, and it is also used globally to describe annual rainfall. Night temperature I dropped because the female protects and warms the nestlings during night time. Also, the day time temperature of the data consisted of eight values per day, whereas the night time temperature was a single lowest value. Wind average was dropped because in this study I wanted to analyze storms in particular. Out of the random factors, Year seemed to have only a minor effect on the function, so I left it out as well. ID and position data remained.

I used generalized linear mixed models (Bolker et al. 2009) and a model inference within an information-theoretical framework (Burnham & Anderson 2002), to asses simultaneously the role of weather variables and the nesting success of both study and control area. I modeled an index of brood size of each year as a function of nest area (study/control) and different weather condition combinations.

I assumed a Poisson distribution and a canonical log-link function for the dependent summed brood size variable. However, the preliminary examination suggested that residual variation was less than expected according to a pure Poisson distribution. It was possible that the data might have reflected inter-weather conditions random dynamics in the number of brood size, so finally I fitted all 63 possible different weather variable scenarios, allowed by the data, into the Poisson equation to see which ones would be the best explaining models for nesting success. To study also the overall effects of weather variable to the whole population these same proceedings, all but without the nest area function, were repeated. I arranged the scenarios in order by their Akaike values. All models in the candidate set (63 models, including the null model) were used. I carried out the analyses using the glmer and lattice functions (in the lme4 library; Bates & Maechler 2009) in R 3.0.2. (R Development Core Team 2010).

5. Results

5.1. *The influence of supplementary feeding*

Nesting success didn’t show any notable divergence between the study area and control area over the 16 years study period. The generalized linear mixed model indicated that there is very little if any advantage to the broods living near the supplementary feeding pond compared to those living in the control area. Approximately same amount of nestlings fledged per nest from both areas. Most of the tested weather models didn’t have significant effect on the osprey population or their reproductive success. Only two models had a better AICc weights than the null model [containing only the random factors; nest number (serial) and nest ID]. Fifty models were within the 95% confidence interval, out of which the best supported model included only the study/control area index, i.e. whether the nest was situated inside the study area or in the control area. Nesting in the study area proved to have a positive impact on the nestling survival. The second best supported model included storms that were three days long in duration and the study/control area index. Storm in this study means wind speed of ≥ 7 m/s. The AICc value of the study/control area index only was 718.5 and the combination of three day storms and study/control area index had an AICc value of 718.9 respectively. The null model had 719.0 AICc (Table 3).

5.2. *Harmful weather*

Most harmful weather types for the control area, proved out to be storms that lasted three days (Table 3). Other weather types, though weaker than the null model, but worth mentioning because of their potential combined effect include rain sum, storms occurring in general and storms ≥ 4 days. When comparing the effects of weather variables to both study and control area populations as a whole (without the division to study area and control areas), I found out that that also there the most significant variables were: 1) three days long storms, 2) rain sum and 3) their combination. These three had AICc weights very close to null model and were within the confidence interval (Table 3).

Table 2. Summary table: Weather factors and breeding success (fledglings/year and fledglings/nest) are presented. This table has the study and control areas combined. Maximum values within the research time have been bolded and minimum values are italic. Storm durations are days.

									Storms					
Year	Chicks / Year	Chick / Nest	Nests	Rain sum (mm)	Rain / day (mm)	Wind (m/s)	Temp (C°)	Night temp. (C°)	Total	1d	2d	3d	Over 3d	MAX d.
1997	129	1.98	65	222.50	3.32	2.60	**18.28**	12.93	4	1	0	1	0	3
1998	135	2.11	64	209.07	3.12	3.51	15.08	11.52	15	2	0	3	1	4
1999	142	2.12	67	99.60	1.49	3.36	17.65	12.49	5	3	1	0	0	2
2000	144	1.97	73	168.05	2.51	**3.97**	15.19	11.21	11	3	0	0	1	**8**
2001	147	2.01	73	153.15	2.29	3.34	16.61	12.18	7	5	1	0	0	2
2002	*127*	1.95	65	180.60	2.70	3.00	17.23	12.89	6	4	1	0	0	2
2003	136	1.97	69	121.00	1.81	*2.13*	17.17	11.76	*2*	2	0	0	0	*1*
2004	133	1.96	68	**276.40**	**4.13**	3.07	*15.07*	10.97	14	6	2	0	1	4
2005	153	2.04	75	204.30	3.05	3.12	16.43	11.78	5	5	0	0	0	*1*
2006	162	2.25	72	*52.80*	*0.79*	3.27	17.38	11.54	12	6	3	0	0	2
2007	137	2.17	*63*	190.10	2.84	3.09	16.28	11.65	9	4	1	1	0	3
2008	149	2.07	72	214.40	3.20	3.84	14.78	*10.52*	13	4	1	1	1	4
2009	163	*1.92*	85	150.30	2.24	3.42	15.67	11.06	13	3	1	0	2	4
2010	**179**	2.03	**88**	156.60	2.34	3.77	18.22	13.39	14	5	3	1	0	3
2011	**179**	**2.27**	79	123.80	1.85	3.37	18.01	**13.49**	**17**	2	1	3	1	4
2012	177	2.01	**88**	172.40	2.57	3.94	15.47	11.35	13	8	1	1	0	3
Average	149.50	2.05	72.88	168.44	2.51	3.30	16.53	11.92	10.00	3.94	1.00	0.69	0.44	3.13

Table 3: Comparison of the significance levels of different weather variables and their combinations. Table shows AICc values, delta AICc values and AICc weights of the null model and eight other best models. The models are ranked by AICc values.

Model	selection												
	(Int)	Study	Storm2	Storm3	StormOver3	Rain_sum	Temp	df		logLik	AICc	delta	weight
2	0.8167	-0.06463						3		-356.229	718.5	0.00	0.060
6	0.7975	-0.06417		0.02631				4		-355.423	718.9	0.40	0.049
null	0.7185							2		-357.477	719.0	0.49	0.047
18	*0.8944*	*-0.06484*				*-0.0004645*		*4*		*-355.558*	*719.2*	*0.67*	*0.043*
22	*0.8828*	*-0.06430*		*0.02890*		*-0.0005222*		*5*		*-354.590*	*719.2*	*0.75*	*0.041*
5	*0.6998*			*0.02660*				*3*		*-356.652*	*719.3*	*0.85*	*0.039*
17	*0.7954*					*-0.0004616*		*3*		*-356.814*	*719.6*	*1.17*	*0.033*
21	*0.7847*			*0.02923*		*-0.0005205*		*4*		*-355.825*	*719.7*	*1.21*	*0.033*
34	*0.5911*	*-0.06468*					*0.0136400*	*4*		*-355.920*	*719.9*	*1.40*	*0.030*

Int = nest ID number; Study = study or control area; Storm2 = storm lasting two days; Storm3 = storm lasting three days; StormOver3 = storm lasting over three days;Rain_sum = Rain sum; Temp = temperature; df = number of variables; logLik = the canonical log-link function; AICc = Second-order Akaike’s information criterion; delta = Difference between the current model and the minimum AICc value; weight = Model weight

5.3. Nesting density

Significant differences in nesting density were detected when comparing the seemingly similar study area and control area. Even though the control area is considerably larger in size than the smaller study area (8,482 km² and 2,827 km², respectively), the control area hosted 125 successful nest sites, over the years, whereas the study area hosted 102 nests. This equals one osprey nest per every 27.72 km² on the study area, whereas on the control area the value is one nest per 67.86 km² (Table 4). Moreover, this difference grows even bigger when regarding the actual land area suitable for nesting (relatively undisturbed old growth forests and mires). Study area had 1,503 km² of forest, where the control area had 5,598 km² of forest respectively, according to ArcGIS analysis. This means that the study area hosts one nest per 14.74 km² of forest, where control hosts one nest per 44.79 km². Likewise when comparing to the areas’ water acreage, the values were 6.19 km² (study) and 9.49 km² (control), respectively. This indicates that a significantly larger osprey population inhabits the study area when comparing the total, nest site suited and foraging suited acreage of the study and control areas.

Table 4. Size of study and control areas (km^2), number of successful nests and size of territory (km^2). Also forest and water area (km^2/nest and %/total forest and water area) are presented. Same variables have also been calculated from ring shape areas within the study area, each 5 km wide. These areas were established to monitor changes of nesting density within the study area and the values indicate that osprey nest closer to each other in the vicinity of the feeding pond. (Average values have small differences because ArcGIS calculates acreage as box shape pixels and the study areas are round.

				Km^2 / Nest	Km^2 / Nest	Km^2 / Nest	AREA (km^2):			AREA % (from total)				
		AREA Total (km^2)	Nests	(total)	(forest)	(water)	Forest	Water	Agriculture	Urban	Forest	Water	Agriculture	Urban
Main:	Study (0–30 km)	2827.43	102	27.72	14.74	6.19	1503.01	631.75	376.17	302.48	53 %	22 %	13 %	11 %
	Control (30–60 km)	8482.30	125	67.86	44.79	9.49	5598.39	1186.60	1123.30	554.24	66 %	13 %	13 %	7 %
Areas:	0–5 km	78.53	3	26.18	6.43	11.08	19.29	33.23			25 %	42 %		
	5–10 km	235.63	10	23.56	10.55	6.80	105.48	67.97			45 %	29 %		
	10–15 km	392.70	20	19.64	10.67	4.09	213.42	81.75			54 %	21 %		
	15–20 km	549.78	17	32.34	18.42	7.43	313.10	126.38			57 %	23 %		
	20–25 km	706.85	19	37.20	20.74	8.20	394.03	155.75			56 %	22 %		
	25–30 km	863.94	33	26.18	13.87	5.05	457.69	166.75			53 %	19 %		
	Average:			27.52	13.45	7.11	1503.01	631.83						

When further dividing the study area (30km in radius) into 5 km wide ring shaped areas surrounding the center, a similar trend within the study area was found. The nearest 5 km ring to Pohtiolampi pond hosted one osprey nest per every 6.42 km² of forest, whereas with the following five rings the acreage was 14.85 km² per nest in average (Table 4). With focus on water acreage the rings had more variation and the nest per km² index was not so clearly divided. Then again, ospreys direct their foraging to all directions depending on the prevailing conditions. Therefore water acreage is not so clear variable on the nest / km² index.

6. Discussion

6.1. The influence of supplementary feeding

This study suggests that the availability of supplementary feeding does not play any particular role in the breeding performance of the osprey. I researched the single and combined influences of several different weather variables but found no indication that the availability of an abundant food source would favor one population over the other. The outcome of this research came unexpected, repealing the first hypothesis about the positive effects of the feeding pond to the breeding success. Indeed there seems to be little if any positive effect to the population from this abundant food source. The only models with a slightly better AICc weight than the null model were: 1) nest site situation (study/control) and 2) nest site situation combined with the effects of three day long storms. The differences in the AICc weights are too small to accurately explain the impact of supplementary feeding on this relationship. It can be assumed that ospreys' reproductive success is positively but weakly associated with the availability of supplementary feeding and to the combined effects of that availability during prolonged storms lasting three days. However, more detailed study than the present one would be useful, since other factors not observed in this study might have had an effect on the outcome of the model. It also seems that there is a subtle correlation with the occurrence of extreme wind and reduced breeding success. In both cases the study area, with the supplementary feeding pond, had a slightly better rate of breeding success than the control. However, these observations had a very small level of significance and thus are too vague to be used as generalization.

The fish abundance of the surrounding lakes and their wind sheltered bays might be a part of the answer why the outcome is as above. The fishing waters of the study and control areas, situated in the provinces of Tavastia Proper and Pirkanmaa, are highly suitable as osprey habitats, both in terms of lake and nest site abundance (Saurola 1993). The area has been one of the foundations of a sustainable population growth in Finland during the years of recovery and continues to host a good number of nesting pairs each summer. The labyrinthine lake area has shallow wind sheltered bays available for fishing. Also Finnish forest laws protect the lake shore forest strips. This provides the ospreys not only with shelter from the wind, but also from potential disturbance, such as human activity.

It has to be further pointed out, that even in habitats with scarce food resources ospreys seem to suffer no significant loss in reproductive success, managing to find sufficient amounts of sustenance for themselves and their brood despite the harsh conditions (Steeger et al. 1991). Prior studies state the proficiency of osprey as a predator. In good weather conditions they require an average number of 2–3 hunting attempts to catch a prey (Grubb 1977; Swenson 1978; Swenson 1979; Machmer & Ydenberg 1990; Castellanos-Vera & Rivera 2007), an average 7,5 minutes to obtain the catch after the start of flapping in midair (Castellanos-Vera & Rivera 2007), an average of 60–85 min of foray duration prior to returning to the eyrie (Green 1976; Stinson et al. 1987) and still having about 50% of their time for rest even when providing food for their young (Heikura 1977; Stinson et al. 1987). Also their food delivery seems to suffer no significant effect from rainy or windy weather, even though the time spend hunting might drag on (Green 1976; Stinson et al. 1987).

The model set put special value on three day long storms. This is partly because in the data set over three day long storms were gathered into “over 3d. storms” -column, because they were scarce. The outcome doesn’t mean that four days long or over storms would not have an effect, they just occur so seldom that they don’t have as strong significance values as the more frequent three day long storms. In this 16 years long study period 10 summers experienced no storms lasting over three days and only the summer of 2000 had a storm longer than four days.

In the models derived in this study, three day long storms occur often also in models inferior to the null model. This might be an indication of a limiting factor for osprey population’s tolerance for prolonged storms when living in an area poorer in fish abundance. In abundant areas like Tavastia Proper and Pirkanmaa the storms probably play no significant role, but they are still first in the models depicting possible causes of brood loss. It could be that in poorer conditions they actually might be a limiting factor for the population's reproductive success. This question should be further studied to come up with a more certified answer.

An insufficient food intake timed just right to the chicks most vulnerable weeks, will most likely lead to the youngest chicks slowed growth and if prolonged, even claim its life. The data used in this study didn't have accurate information concerning the chicks that died in the nest. The death was recorded only if the remains were found. I believe, however, that the data used in this study is mostly valid and describes the actual situation in the best obtainable manner. Unfortunately an accurate evaluation of the effects of predation on the nesting success can't be calculated from this data. If remains of a chick or a clutch have been found in or near the nest they have been simply marked on our data as "dead chick(s)" or "unsuccessful nestings". Be the cause predation, weather or other reasons, no specific cause of death has been recorded. However, osprey has no established position as any predator's main prey, not even a minor one. If osprey falls prey to white-tailed eagle (*Haliaeetus albicilla*), Eurasian eagle owl (*Bubo bubo*) or pine marten (*Martes martes*) it is mainly because of the actions of an opportunistic hunter individual, not because of the habits of the whole hunter population and can be considered as rare occurrences (Kirschbaum & Watkins 2000).

6.2. Harmful weather

The results of supplementary feeding and weather modeling show that most harmful weather types for osprey nestlings are: 1) three day long storms, 2) heavy rain and 3) combination of rain and storm. This type of association has been suggested by many scientists over the years. Historical records may provide additional insight. Odsjö & Sondell (1976) suspected the unusually cold and rainy periods, just when the nestlings are small and can't regulate their body temperature, to be the reason behind ospreys' poor reproductive success in the Swedish lake area in 1971. In that year particularly bad weather was predominant during the first and second week after hatching. Sweden is a good comparison to this study, because the habitat and weather conditions are rather similar. This study also charted these same kinds of weather variables and found a few very interesting weather anomalies to look into. First was the big storm in 2000. This storm hit on the 10th of June just after the chicks had hatched and continued eight days straight until finally ceasing in the evening of 17th. Also 8th and 9th of June were already windy, so this equals 10 days of choppy water just when the chicks had hatched. On that year, also the day and night temperatures were below average. The nesting success was lower than average that year, producing 1.97 fledglings per nest (see: Table 2.). Next interesting example pair in this data was the years 2004 and 2006. 2004 was particularly rainy. Actually, it was the rainiest year in our research period. The rain sum of 2004 was 276.40 mm. That year the day temperature average was the lowest of the whole data and also night temperatures were below average. This might have been one reason why only 1.96 chicks per inhabited nest fledged that year. Then again the year 2006 was particularly low in rainfall, with only 52.80 mm rain sum. That year the nesting success rate was 2.25 fledglings per nest. However, one has to be critical when drawing conclusions out of these results. The same summary table (Table 2.) that shows these correlations also tells that the worst summer in nesting success had absolutely no extreme weather variables. The weather was nothing but average on 2009, yet the reproductive success was only 1.92 fledglings per nest that year. Again the year 2011, with the biggest breeding success (2.27 fledglings / nest), had the most storms of the whole data set. This proves that even though weather variables might seem to have an effect to ospreys breeding success, the final outcome is nothing more than unpredictable in a short study time. In longer run weather anomalies seem to have no effect on breeding success, according to my study. One thing possibly distorting the outcome of this study is that within my study area most ospreys nest in human made nests that are more stable than osprey made ones. This can cause nests not falling so easily in strong wind velocities and thus resulting a lover annual chick loss.

6.3. Nesting density

According to my study on the nesting habitats and nesting density of the study and control area, it can be assumed that the osprey pairs nesting near the feeding pond benefit from the additional food resource. As predicted in the third hypothesis of this study, significant differences in the nesting density between the study and control areas were detected. Differences could also be seen within the study area, depending on the distance from the nest to the feeding area. Osprey nesting density was 2.44 times higher in the study area than in the control area when measuring the total acreage. It was three times higher when studying the nest site abundance and 1.53 times higher when studying the foraging water abundance. When further dividing the study area into 5km wide rings surrounding the center, a similar trend was found. The inner most circle (0–5 km), nearest to the feeding area, had 1.64 times higher nest density than the next circle (5–10 km) and 2.27 times higher nest density than the next five circles (5–30km) in average (see: Table 4). These results indicate that ospreys try to centralize their nesting near an abundant food source, thus creating an area with higher juvenile productivity, beneficial to the whole local population and to the dispersal rate of the species. However, these results are still too vague and more research is needed to answer this assumption more thoroughly. Since there might be other unknown factors influencing the nesting density within the study area one must not fall into hasty suppositions. Many type of factors, other than the feeding area, may directly or indirectly influence the ospreys' nesting density.

Ecotourism is generally considered harmful to most studied animal species (see Krüger 2005; Steven et al. 2011) and having a negative impact on the local bird species and populations in 88 % of the case studies (Steven et al. 2011). This study, however, noticed no negative effects caused by the nature tourism to the osprey, on the contrary. Ospreys came again and again to the feeding area. They got supplementary food, did not lose their hunting skills, nor got used to humans. They were able to live more densely near the feeding area and by doing so, produce more young per km² profiting the population.

I believe that despite its handicaps ecotourism business is beneficial in a sustainable sense. When it is accomplished in a win-win relationship with the species, causing no stress to the bird and on its own voluntary and conditions, I see no argument against this type of nature tourism. This study highlights that sustainable ecotourism, benefiting the birds, the local economy and our desire to experience nature first hand, without disturbing it, is possible with enough effort.

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8. Appendix

Map 1:

Study and control area. “X” marks the location of Pohtiolampi osprey center (Kangasala (61° 26.876’ N, 24° 7.705’ E) in the middle. Smaller circle marks the border of study area and larger circle marks the border of control area. Land use types are indicated in the map with colours. Green indicates forests, yellow = agriculture, red and purple = populated areas (human) and blue = lakes. The big red area, left from the X, is the Tampere-Nokia-Kangasala coalition.